



Cryogenic Target Production for Commissioning Tuning Techniques and the First Ignition Tuning Campaign on NIF

**Presentation to
20th Target Fabrication Meeting
Santa Fe, New Mexico
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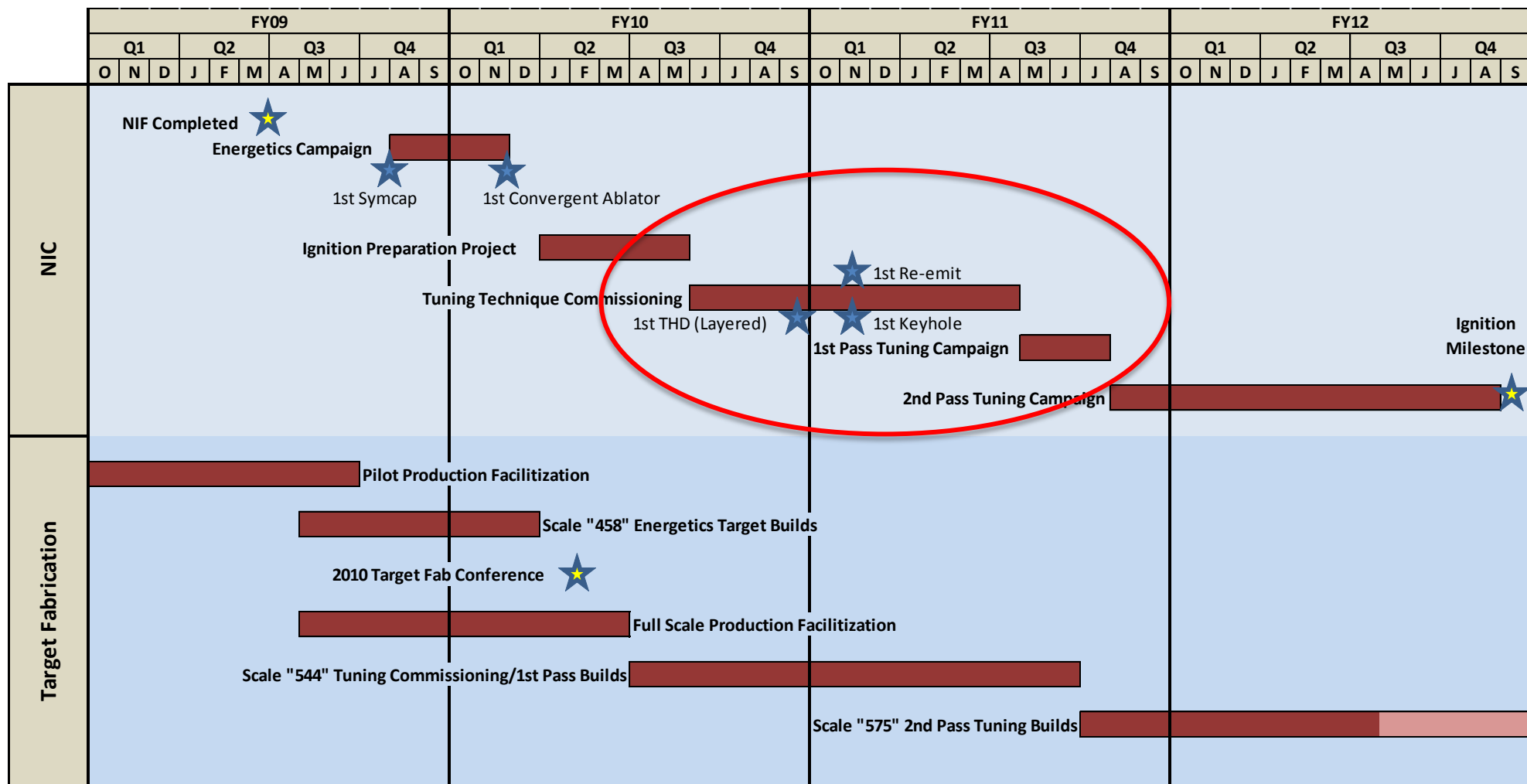
Lawrence Livermore National Laboratory • National Ignition Campaign

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- LLNL, General Atomics, Akima, Schafer

NIC/ Cryo Target Fabrication Summary Schedule



Two significant build campaigns have been completed since 2009 and a third is in progress

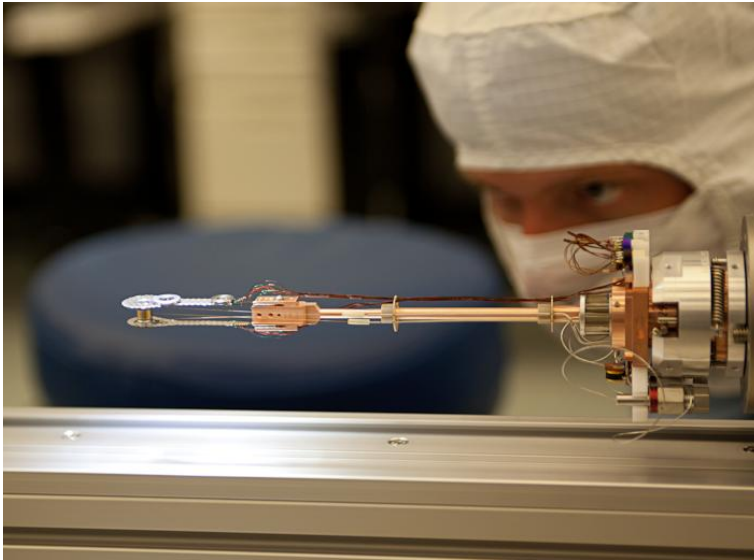
- **Energetics (July – Dec 2009)**
 - Validated 280-300eV hohlraum temperature capability
- **Tuning Technique Commissioning and 1st Pass Tuning (Nov 2010 – July 2011)**
 - Commissioned tuning diagnostic techniques, defined the foot of the ignition laser pulse, 1st – 4th shock timing, and power of the 1st – 3rd shocks
- **2nd Pass Tuning (July 2011 – Present)**
 - Consists of four campaigns addressing:
 - Shape
 - Pressure
 - Mix
 - Performance

Cryogenic target assembly is carried out in a 3000 ft², class 100 clean room at LLNL



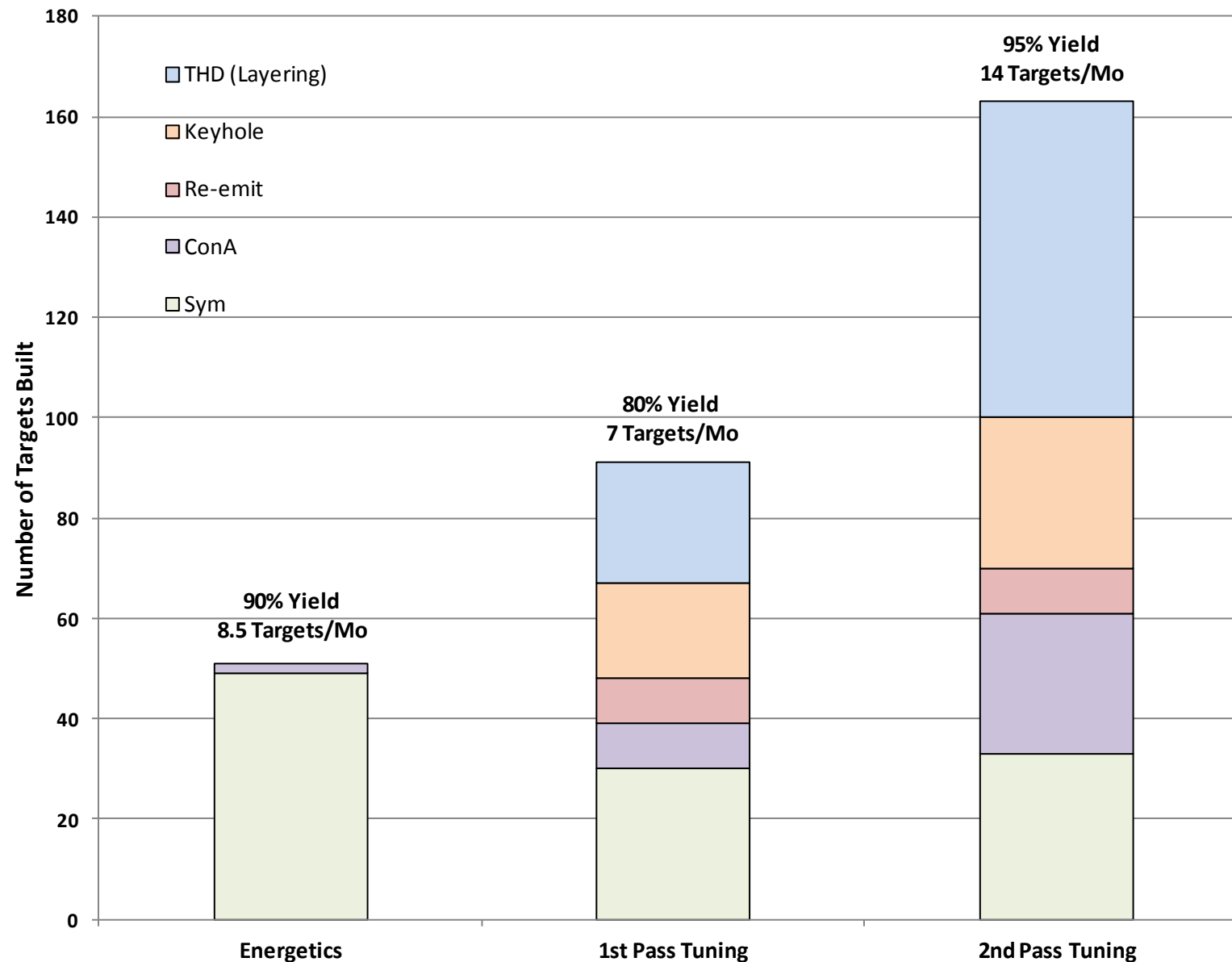
The production floor consists of four integrated product lines focused on the capsule, thermal-mechanical system, tents, and diagnostic elements

During 1st pass tuning builds, 15 technicians worked on ~30 assembly stations to produce up to 4 targets per week

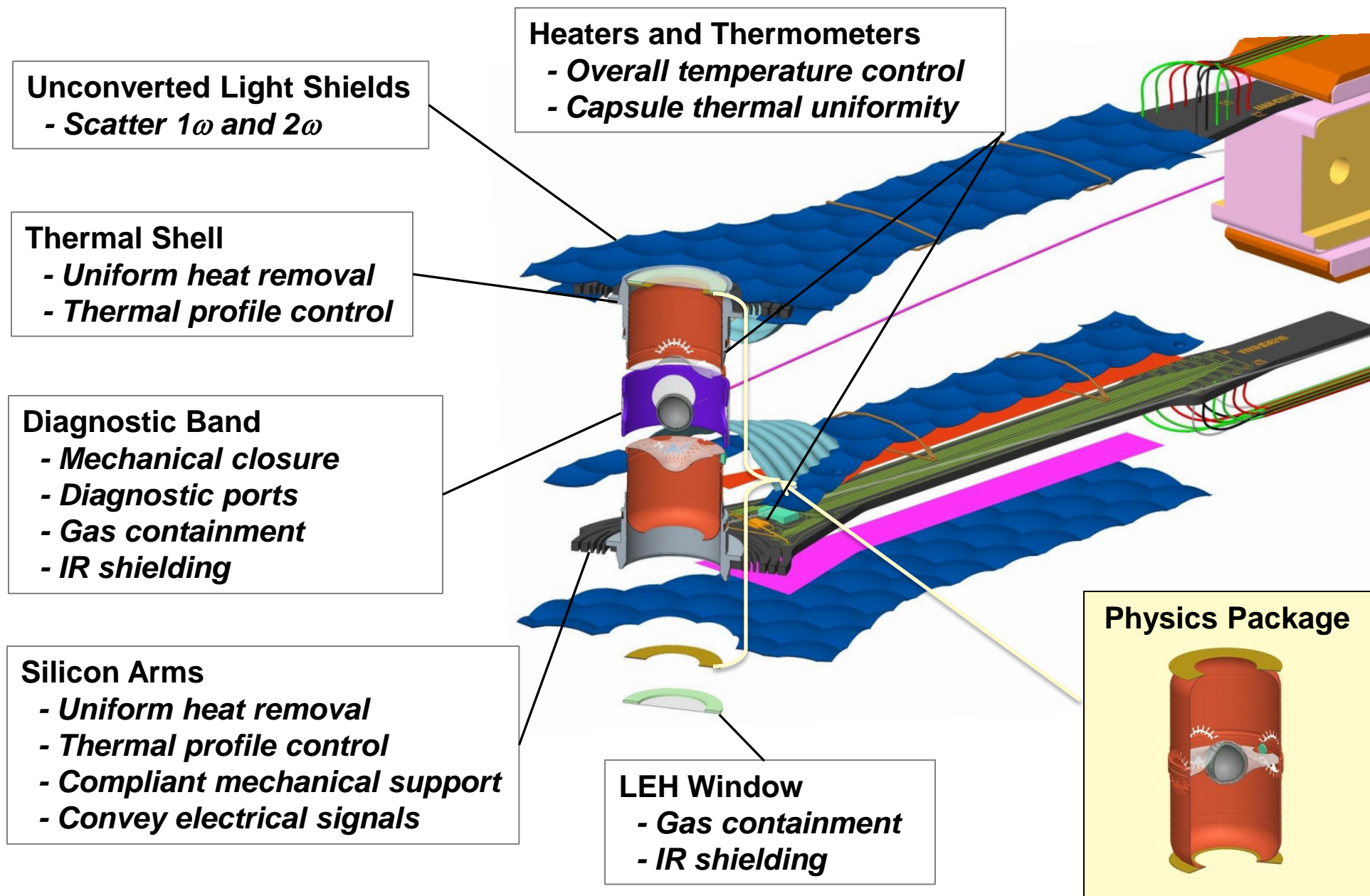


We now have the capacity to produce one target per day as a result of increased technician staffing and process improvements

Cryogenic target production has ramped up to meet NIC demand – more than 300 targets to date



The ignition platform enables the use of common tooling for most elements of tuning target assembly

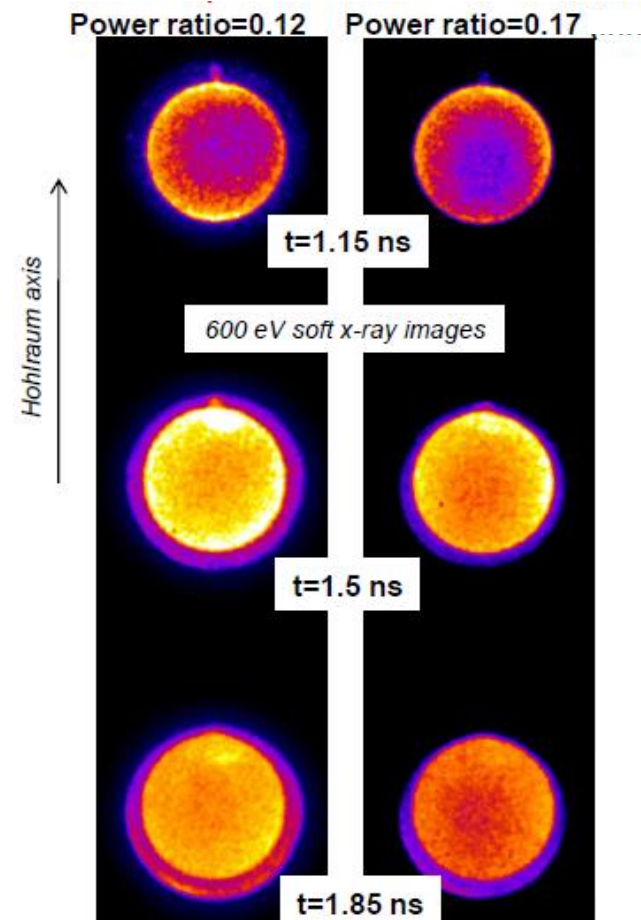
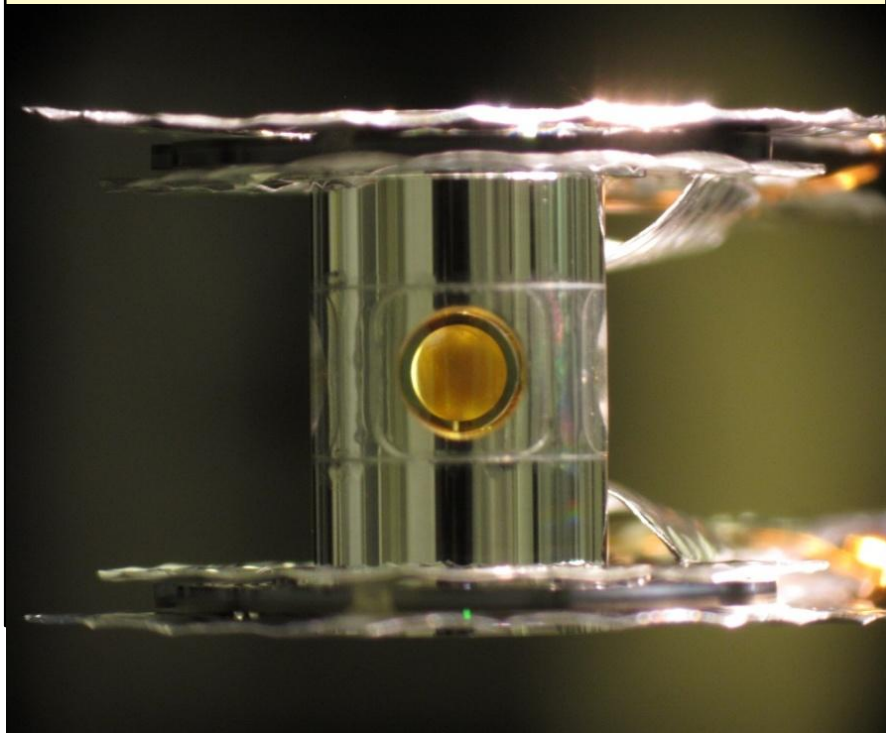


NIC targets allow progressive tuning of the laser pulse for optimal hohlraum coupling and shock timing

- **Re-emit**
 - Enables tuning of the foot of the laser pulse based on early radiation symmetry diagnosis
- **Keyhole**
 - Enables tuning of the laser 1st-4th shock timing and power levels based on shock timing and velocity diagnosis
- **Convergent Ablator**
 - Enables additional tuning of the implosion velocity based on mass remaining diagnosis at bang time
- **Symcap**
 - Enables wavelength and power ratio tuning for late time shape control
- **Ignition (layering targets)**
 - Enables the validation of the tuning parameters through capsule symmetry and neutron yield diagnosis

2010/11 Tuning Targets – Re-emit

Re-emit

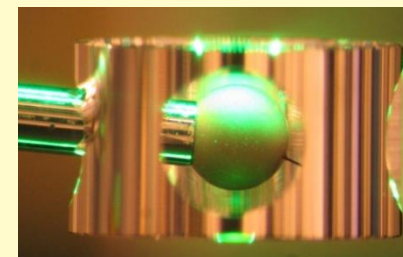
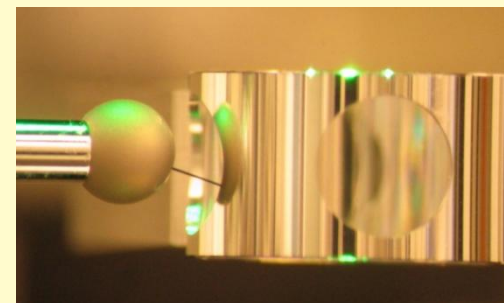
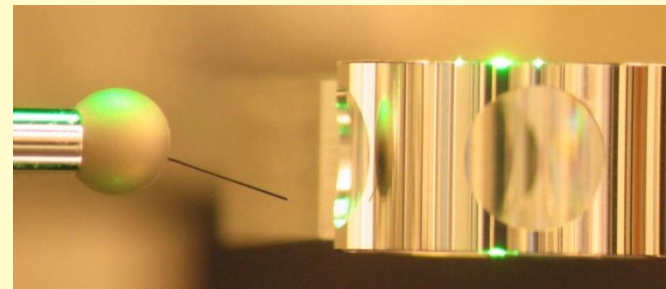


Early time radiation symmetry at the capsule was tuned with Re-emit targets by changing the power ratio of the inner and outer beams

Re-emit Specifications

- Ignition platform
- 7 μ m thick Bi coated CH capsule
- 80 μ m x 80 μ m diamond stalk
- 0.5 μ m thick polyimide diagnostic patches on the equator, 180 deg apart

Capsule Assembly into the Diagnostic Band

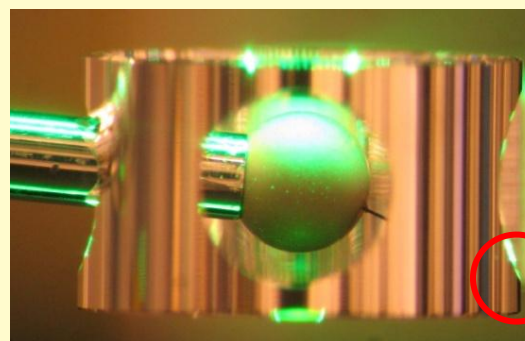


A tenting membrane for the capsule cannot be used in Re-emit targets due to soft x-ray emissions that affect the experiment

Re-emit Assembly Challenges

- Capsule assembly bond strength
 - The first three assemblies failed due to weak bonds at the capsule and diagnostic band (shown in red circles)
- Stalk strength
 - 40um sq diamond stalk fractured once the capsule bonds were made more robust

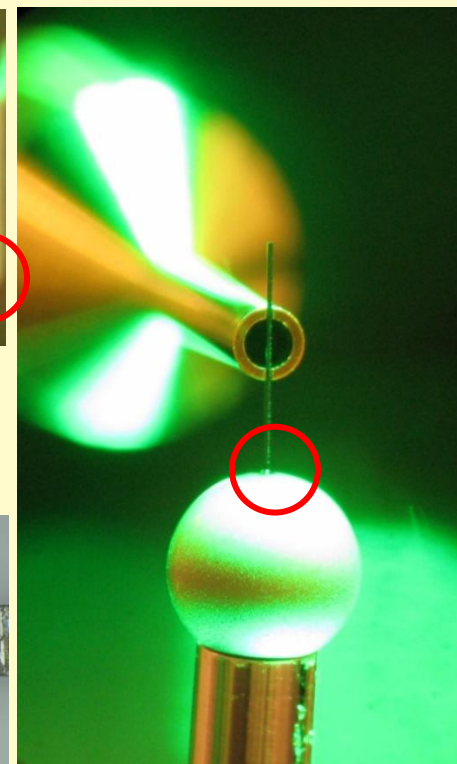
Capsule Assembly Elements



Capsule-to Diagnostic Band Joint



Diamond Stalk

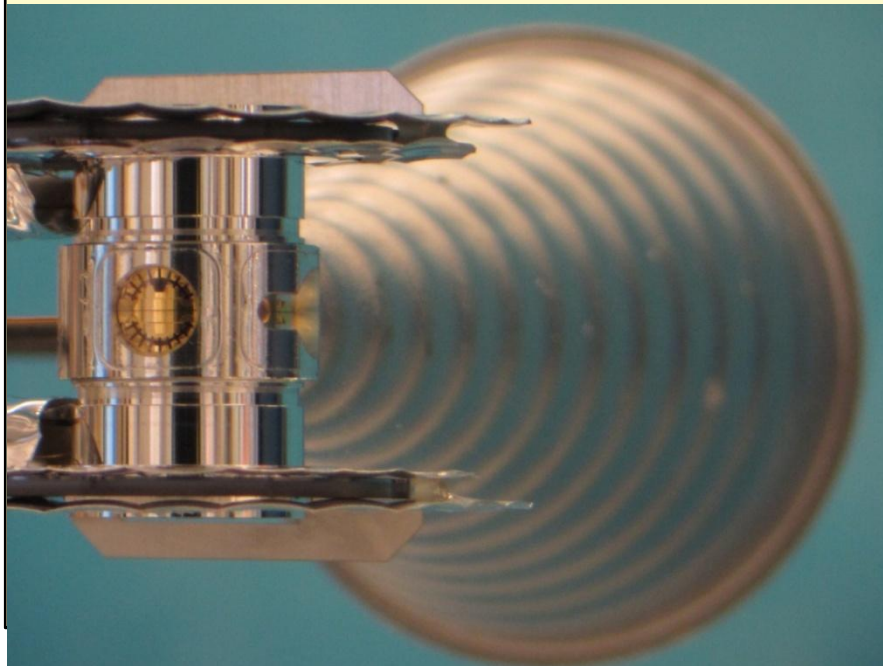


Cone-to-Stalk Joint

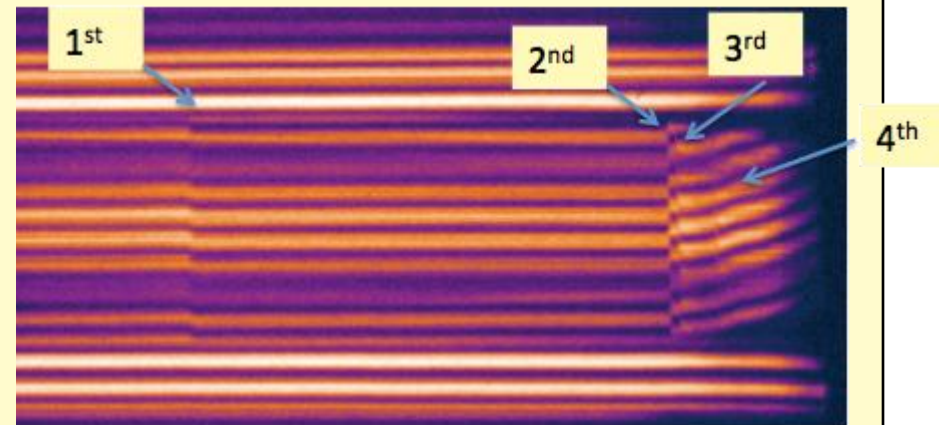
See poster presentation on “Ignition Tuning Target Assemblies..” by K. Segraves

2010/11 Tuning Targets - Keyhole

Keyhole



**VISAR Diagnostic Image of
1st – 4th Shocks**

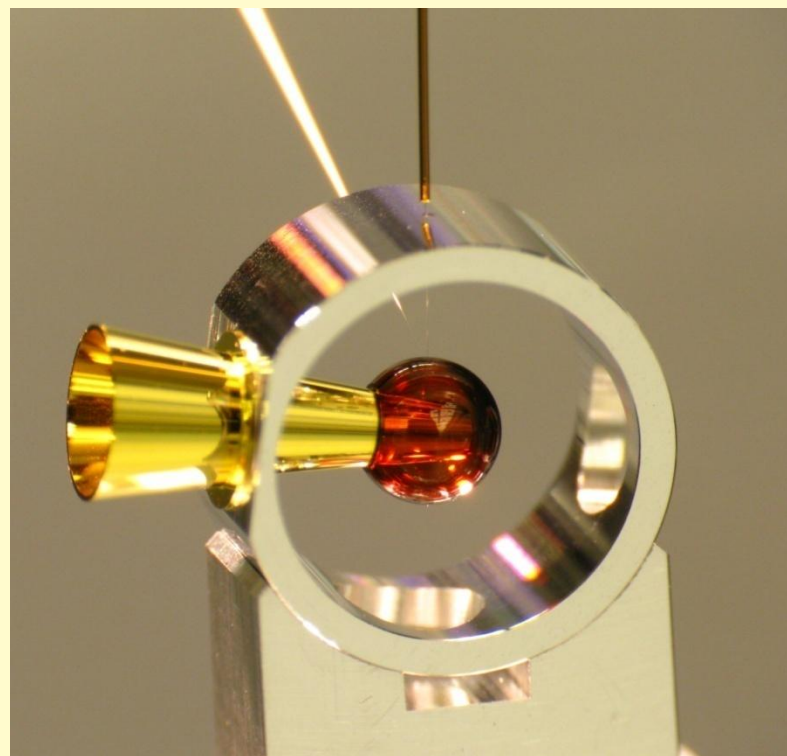


Shock timing and power levels of the ignition laser pulse were tuned using two targets types; 1st – 3rd Shock Keyhole and 4th Shock Keyhole

Keyhole Specifications

- Ignition platform
- Cone-in-capsule
- Sealed cone volume (Key1-3) or capsule volume (Key4) for D2 fill
- Quartz window for diagnostic viewing (Key1-3)
- Cone and LEH shields to prevent blanking of the VISAR diagnostic

**Diagnostic Band Subassembly
During Fill-Tube Insertion**

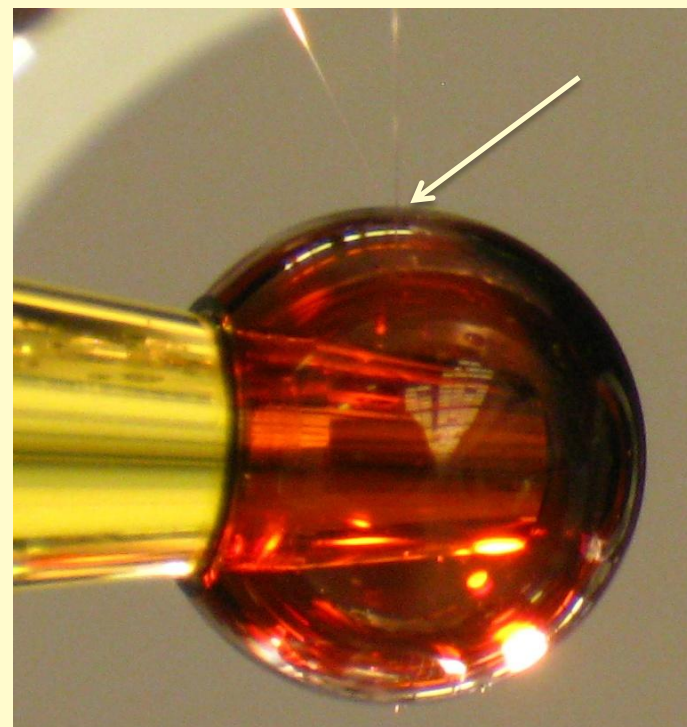


Keyhole targets are among the most difficult to assemble, requiring new methods for fill-tube attachment and fabrication/installation of complex shielding

Keyhole Assembly Challenges

- **Fill-tube installation**
 - **4th shock Keyhole targets** required assembly of the fill-tube to the capsule while inside the diagnostic band
 - **1st – 3rd shock Keyhole targets** required assembly of the fill-tube to the cone
 - **Leak testing of the diagnostic band subassembly containing a cone, capsule, fill-tube, and quartz window (Key 1-3 only)** was required prior to final assembly

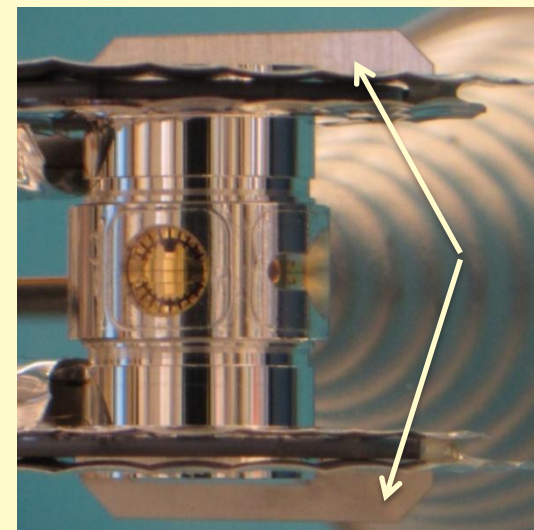
10um Diameter Fill-Tube Bonded to Capsule with 50um Glue Radius



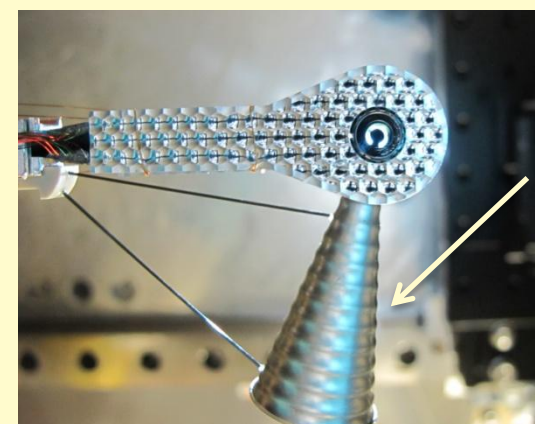
Keyhole Assembly Challenges

- **Shield installation**
 - LEH (Laser Entrance Hole) shields required tight positioning tolerances to allow viewing of the target alignment fiducials without clipping the incoming 50° beams
 - The cone shield could not contact the cone, requiring the shield to be precisely positioned and suspended by carbon rods
 - In-process metrology using an Optical Coordinate Measurement Machine (OCMM) was required

LEH Shields



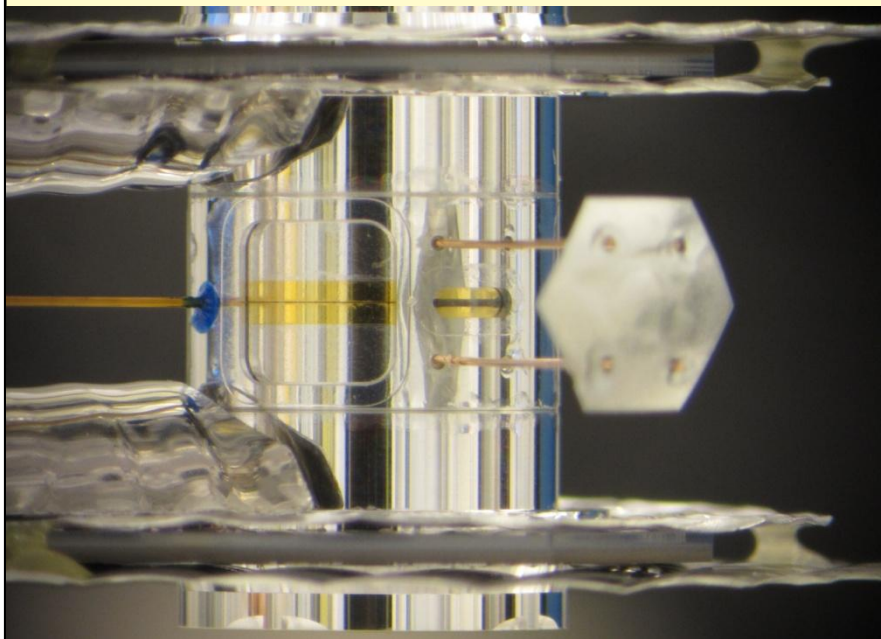
Cone Shield



See poster presentation on “Ignition Tuning Target Assemblies..” by K. Segraves

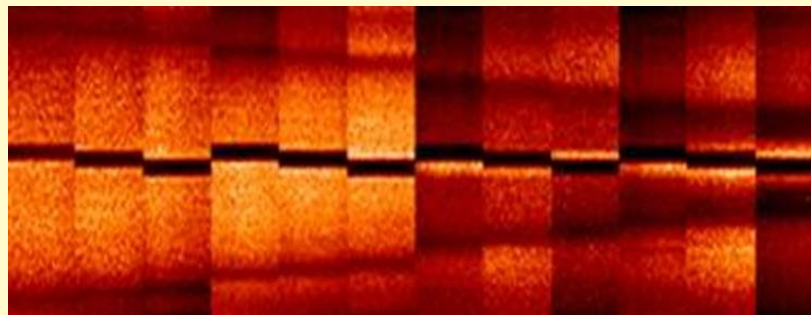
2010/11 Tuning Targets – Convergent Ablator

Convergent Ablator



Diagnostic Image of Capsule Diameter Over Time

Capsule Diameter



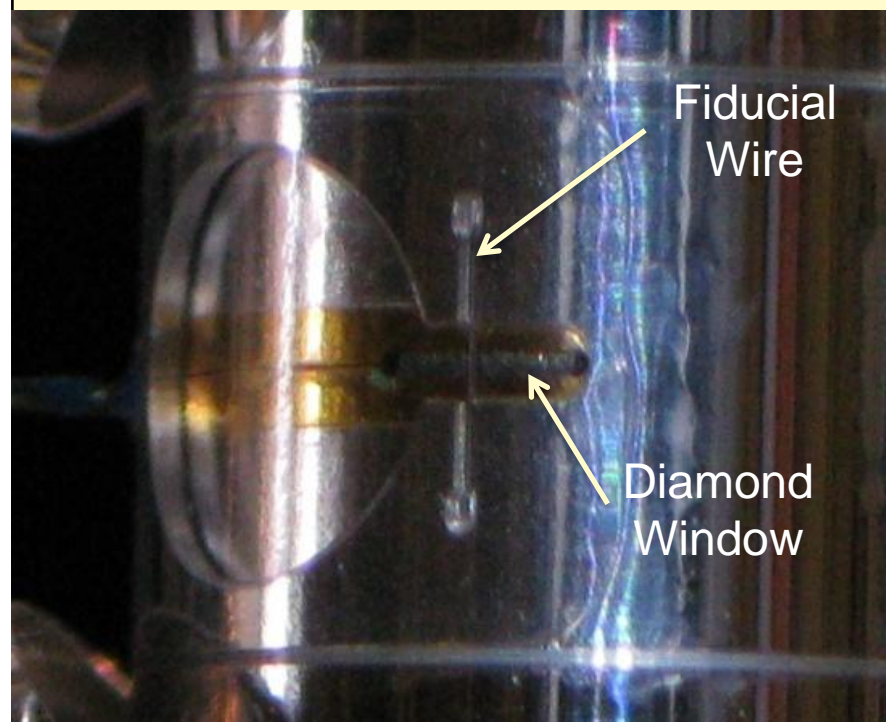
Increasing Time >

Convergent Ablator targets provide a means for estimating mass remaining at bang time through measurement of the moments of $\rho(r,t)$

Convergent Ablator Specifications

- Ignition platform
- Symcap capsule fill-tube assembly
- 110nm formvar tents
- 5um thick Zinc backlighter
- Diamond diagnostic window
- 50um diam. Tungsten fiducial wire

Fiducial Wire Positioned Mid-Point of the Diamond Viewing Window



Installation of the fiducial wire and backlighter onto the diagnostic band early in assembly created a delicate component that needed to be robust through final assembly and bonding

Convergent Ablator Assembly Challenges

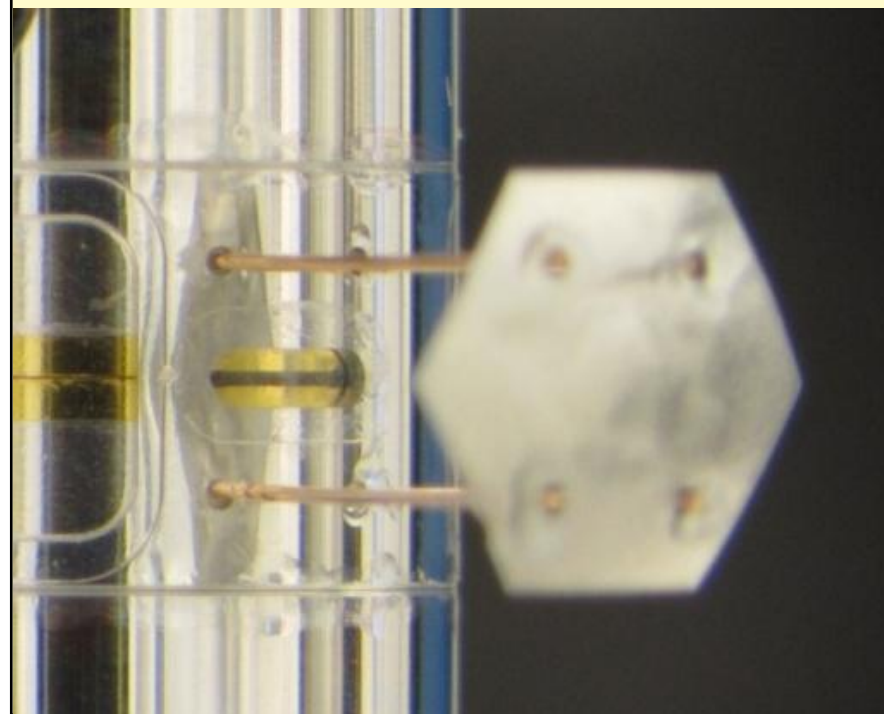
- **Backlighter**

- The backlighter had to be installed early in assembly to allow metrology prior to being obscured by the thermal arms
- Curvature of the backlighter foil needed to be retained during assembly
- Four mounting legs made from 36 gauge phosphor bronze wire, had to maintain the foil apex position within 200um of the diag. axis

- **Bonding**

- Window installation and sealing was made difficult by the presence of the backlighter and fiducial wire

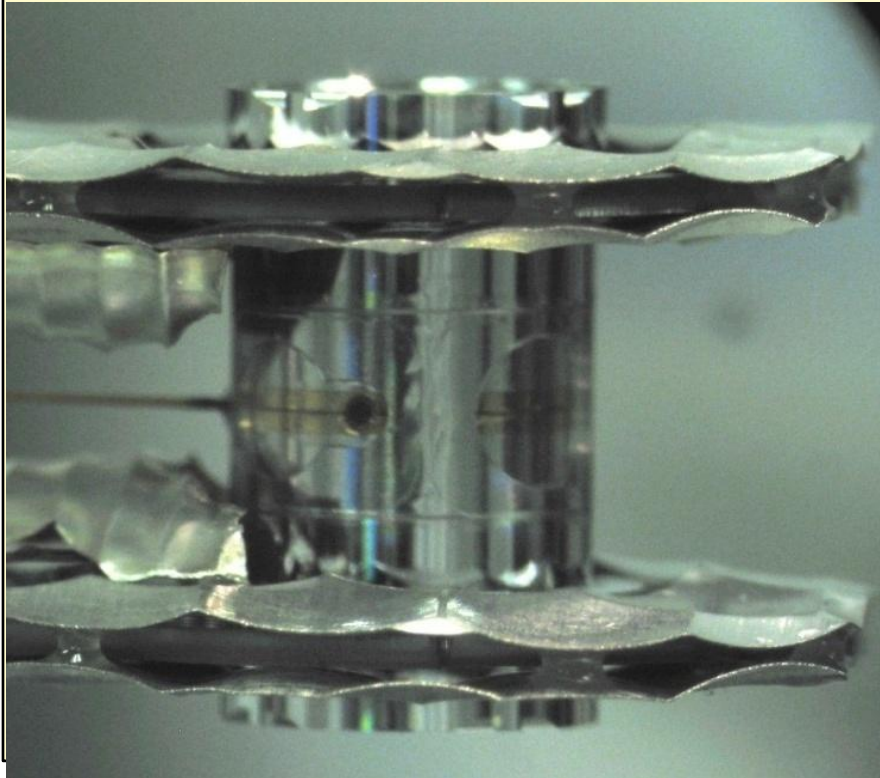
Backlighter Foil Suspended ~2.7mm Off of the Diagnostic Band



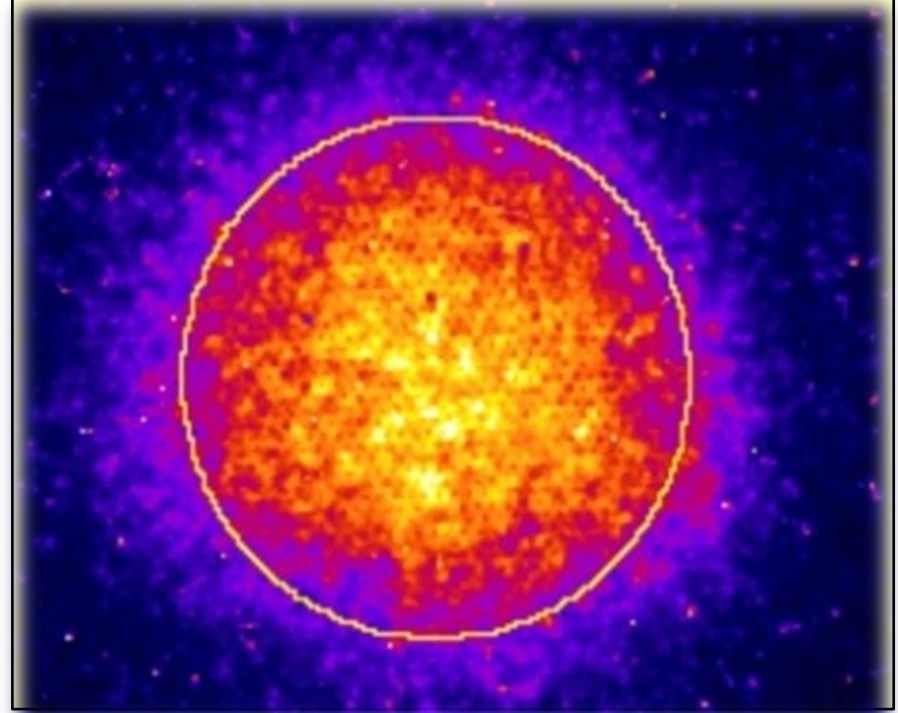
See poster presentation on “Ignition Tuning Target Assemblies..” by K. Segraves

2010/11 Tuning Targets - Symcap

Symcap



Implosion Symmetry at Peak Velocity Measured with the Gated X-ray Diagnostic

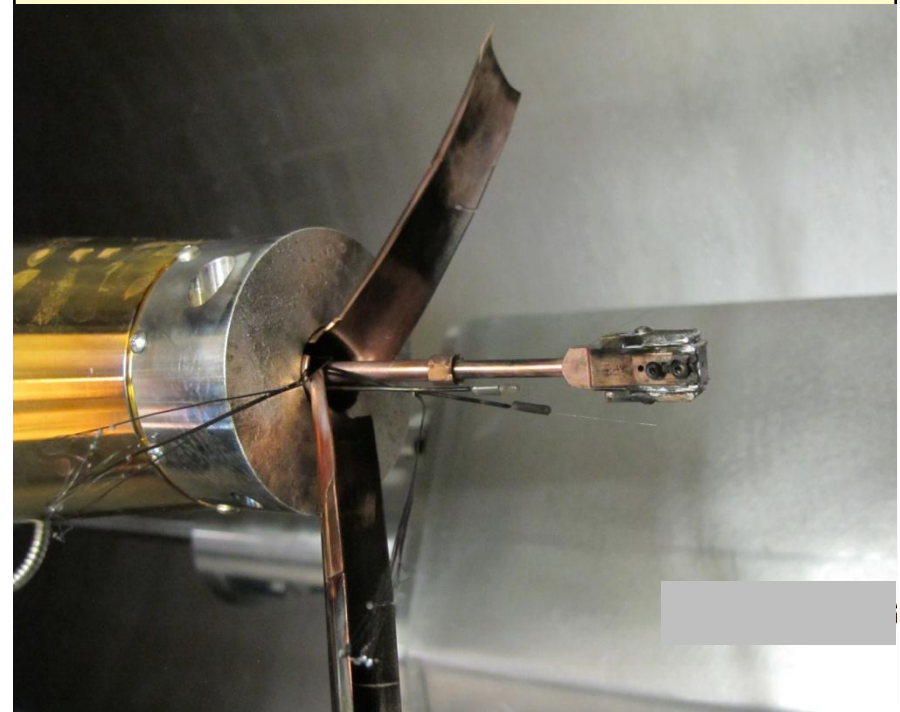


Symcaps used in the 2010-2011 campaigns were a scaled-up version of the design fielded in the Energetics campaign in 2009

Symcap Specifications

- Ignition platform
- Symcap capsule fill-tube assembly
- 110nm formvar tents

**Remnants of a Symcap Target
Shot on NIF**



Our assembly experience to date had been with Symcap targets, so when yield issues began to arise with the larger scale, we had to take a closer look at our processes

Symcap Assembly Challenge

- **Tent failure at assembly**
 - Hohlraum geometry at the tent interface was not optimal
 - Asymmetry in the tent design was causing the capsule to drift radially during target closing
 - Formvar solution was deteriorating over time
 - Epoxy application to the hohlraum tenting surface allowed uncured epoxy to remain after assembly

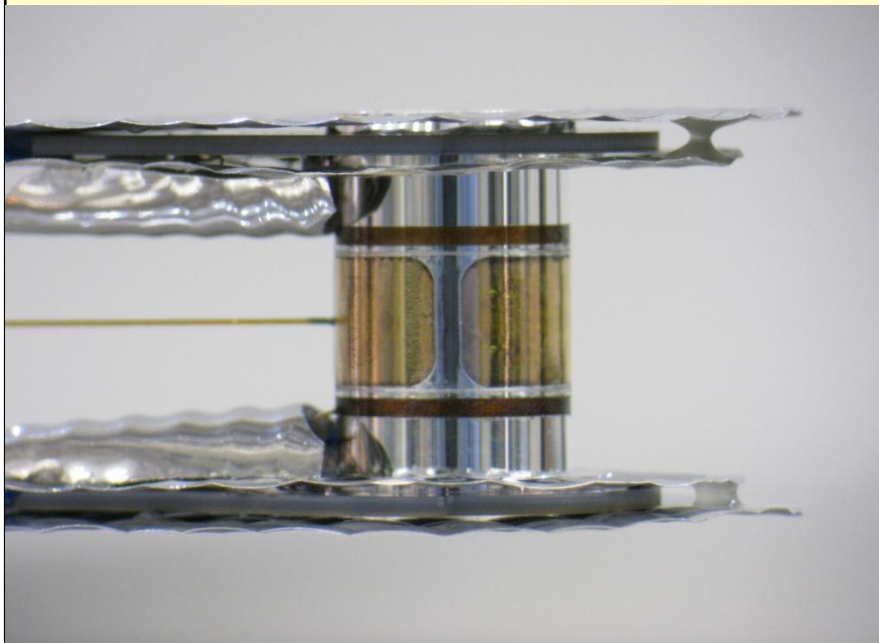
**View of Lower Tenting Surface
Prior to Assembly**



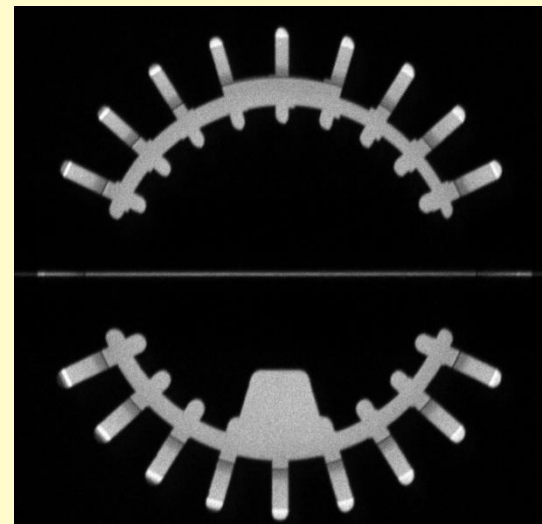
See oral presentations on “Environmental Effects on Tent Processing...” by Michael Stadermann and “The Influence of Chemical and Mechanical Effects on the Stability and Strength of Formvar Tents” by Phil Miller

2010/11 Layering Target – Ignition or THD

Layering



**Radiograph of an Ice Layer
Through the Hohlraum “Starburst”**



The first layering target was fielded on September 29th, 2010 with a THD fuel mixture and all the functionality required for ignition

Layering Target Specifications

- Ignition platform
- Ignition capsule fill-tube assembly
- 110nm formvar tents
- Ice layer shimming heaters
- DT or THD fuel reservoir

1st Layered Target Shot on NIF

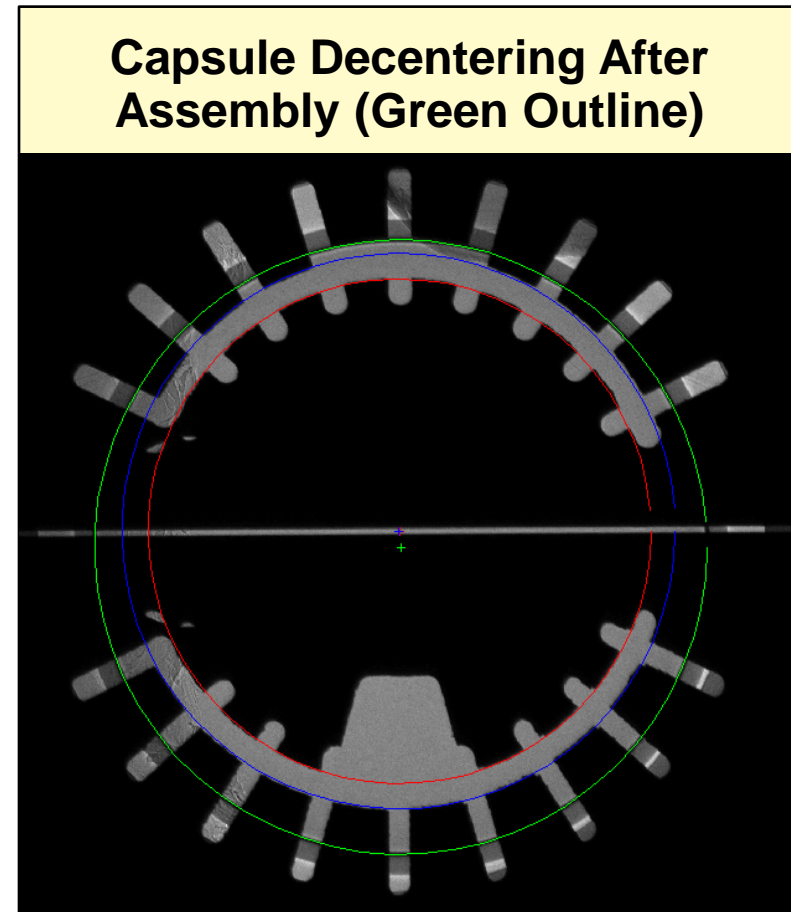


A significant change in layering target design and fielding operations allowed the use of an external fuel reservoir, extending the life of the target on NIF and eliminating the need to remove the target for fuel replacement

Layering Target Challenges

- **Capsule Sag**

- Capsule position was found to move over time in the direction of gravity
- Adhesive vapors from bonding were causing the tents to degrade after the target was sealed
- The assembly process had to be modified to allow vapor purging prior to final sealing of the target



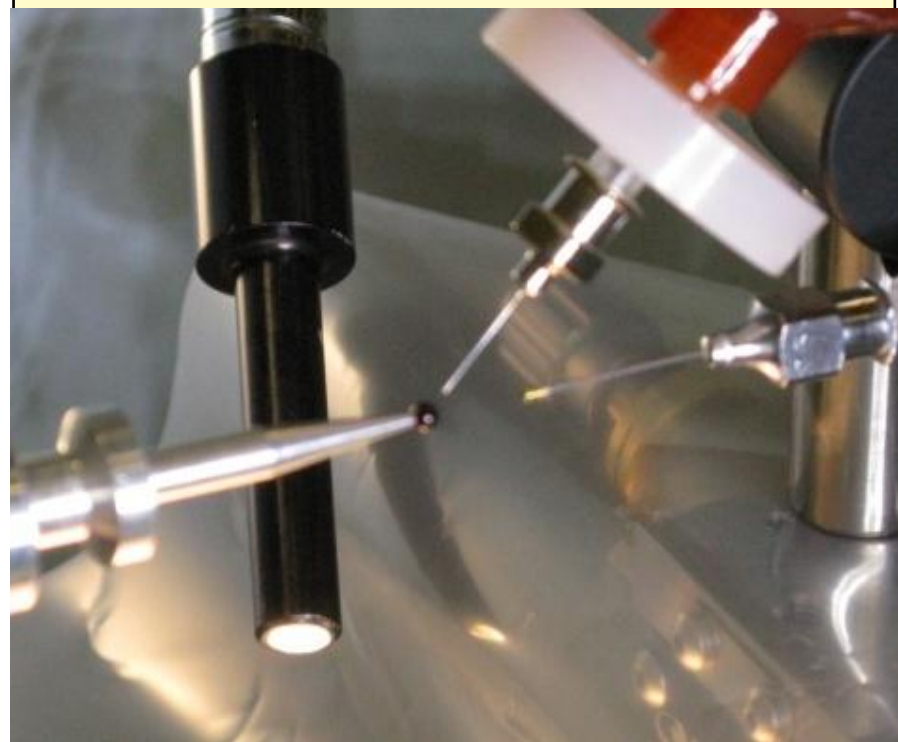
See poster presentation on “Bonding Improvements...” by Jean Jensen

Layering Target Challenges

- **Capsule Contamination**

- Capsule particulate can be a cause of mix during the implosion and therefore identifying and removing all particles over $30\mu\text{m}^3$ is required
- Capsule particulate mapping and cleaning were attempted early in the tuning campaign that caused CFTA yield issues and were not adequate to meet requirements
- The clean room facility required additional flow units localized where the CFTA was exposed during assembly

Prototype Capsule Cleaning System

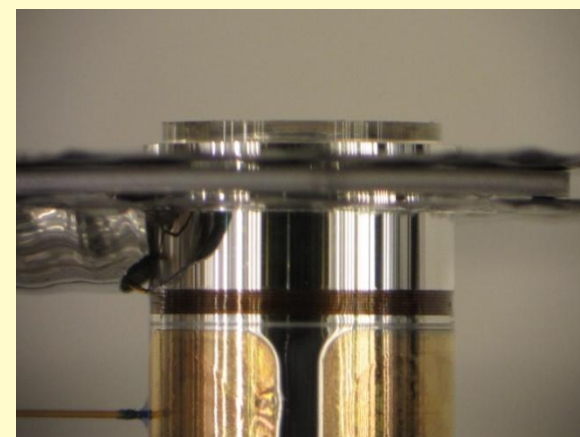
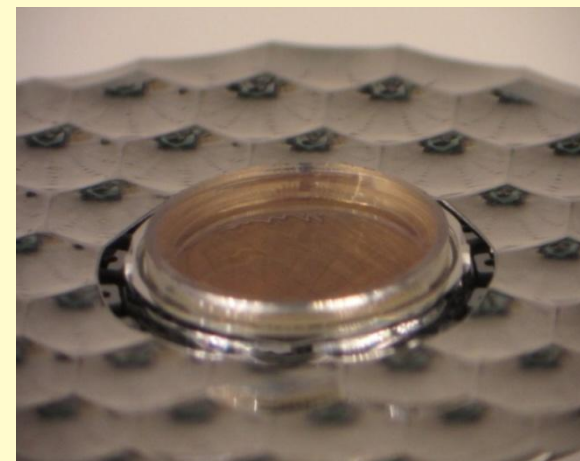


See oral presentations on “A Solvent Cleaning Process...” by Sal Baxamusa and “Strategies to Remove Particulate...” by Suhas Bhandarkar

Additional Assembly Challenges for All Target Types

- **Laser Entrance Hole (LEH) window condensate**
 - Icing of the LEH windows from residual gasses in the vacuum chamber was observed during fielding
 - The condensate ice impeded laser light transmission
 - An outer laser entry window was developed, called a “storm window” and a retrofit of built targets was required

Outer Laser Entry Window

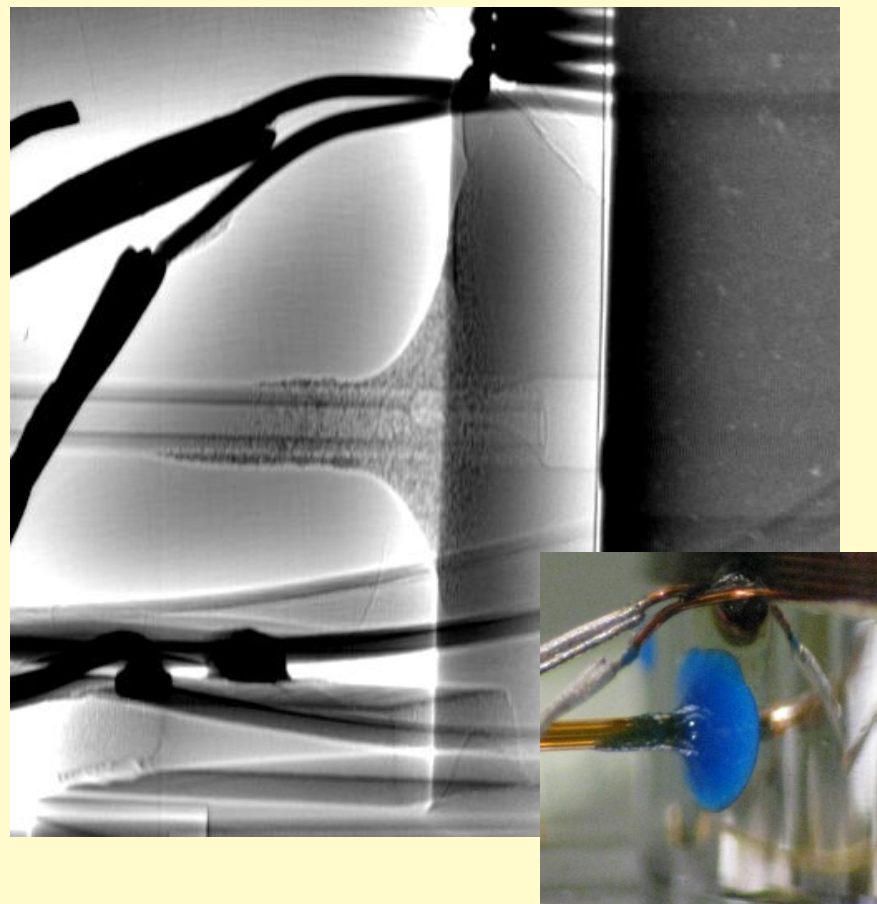


See oral presentation on “Prevention of Residual Gas Condensation...” by Suhas Bhandarkar and poster presentation on “Outer Laser Entry Windows...” by Joe Florio

Additional Assembly Challenges for All Target Types

- **Tamping gas line plugging**
 - During proofing a number of targets were found to have plugged tamping gas lines and leak paths through the epoxy fillet of the gas line bond
 - Residual epoxy from the hohlraum insertion process and the hohlraum/TMP interface geometry were found to cause undesirable back-pressure during the bonding process
 - Assembly processes were modified to mitigate the problem along with long term component redesign

X-Ray Image of Fill-Tube Bond



See poster presentations on “Bonding Improvements...” by Jean Jensen and “Hohlraum Insertion Station Improvements...” by Randy Strauser

1st Pass Tuning Campaign Summary

- Demonstrated our ability to build all of the NIC tuning targets to specification
- Demonstrated our ability to overcome technical challenges with a strong team made up of production, engineering, and S&T resources
- Addressed the need for an increase in production rate to keep pace with 2012 NIC shot demand through additional capacity and process improvements
- Established the processes necessary to quickly respond to changes

7th Target in 7 days

December 2011



What's Ahead?

- Continue supporting the 2nd pass tuning campaign, which is putting production agility to the test as we learn more with each shot
- Demonstrate our ability to meet the capsule cleanliness specification with cleaning and 4pi inspection
- Focus on improving the ignition target design:
 - addition of a Mode 1 shim heater
 - modified starburst
 - 5um capsule fill-tube
 - various capsule designs

Layered Compton Radiography Target



NIC

